Interstellar Circular Polarization and the Dielectric Nature of Dust Grains

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We have reexamined the implications of the observed relationship between the wavelength dependence of interstellar circular and linear polarization. Mie theory calculations for grains with various optical constants demonstrate that any population of grains which matches the observed wavelength dependence of linear polarization also yields the correct cross-over wavelength of circular polarization. The coincidence of the peak wavelength of linear polarization and the cross-over of circular polarization is therefore independent of the optical constants of the grains and cannot be used as a critical constraint on grain properties. The observed relationship instead reflects a more fundamental connection between linear and circular polarization which has been derived from the Kramers-Kronig relations by Shapiro (1975). Our numerical results fully support Shapiro's conclusions and demonstrate that the apparent upper limit on the visual absorptivity of polarizing grains deduced from earlier Mie theory calculations (Martin, 1972) was spurious and resulted from a violation of the Kramers-Kronig relations in the assumed optical constants of the particles.

The Kramers-Kronig interpretation of circular polarization can be used to place constraints on linear polarization outside the wavelength range in which it has been observed. We use this approach to show that the peak observed in the visual is likely to be the only significant feature in the linear polarization curve, which therefore appears to be well approximated at all wavelengths by the Serkowski formula.

A synthesis of available laboratory data has been used to analyze the properties of dielectric core-mantle grains as the source of visual extinction and polarization. The mantle material is likely to have a low effective energy gap (below 1 eV) and a relatively high visual absorptivity (observations of the albedo of grains suggest an imaginary part of the index of refraction at least as high as 0.15). A multipopulation model, which incorporates the silicate core - organic refractory mantle grains (Hong and Greenberg, 1980), is shown to satisfy all the available constraints on grain properties in the visual.